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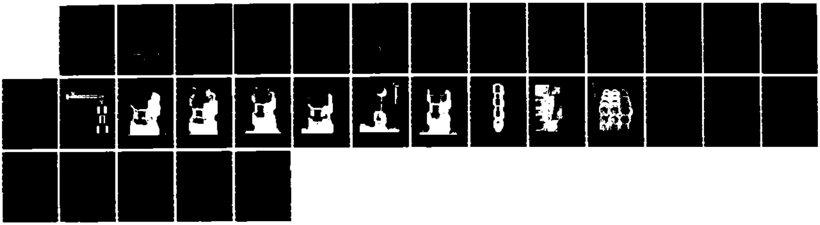

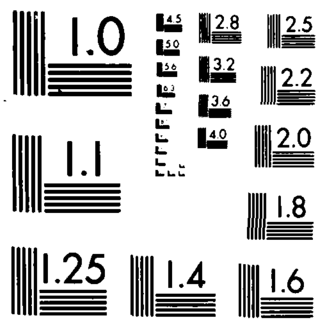

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TECHNICAL REPORT ARAED-TR-86027

BLOW-MOLDED PLASTIC CONTAINER DEVELOPMENT PROGRAM FOR LARGE CALIBER AMMUNITION

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A research and development program for determining the feasibility of designing a plastic container for packaging 105-mm tank ammunition was conducted. The selected approach incorporated the blow molding manufacturing process in conjunction with the use of high density polyethylene.

Described in this report is a start-to-finish account of the development of the plastic tank round container. Included are the design changes which were made

(cont)

20. ABSTRACT (cont)

as unforeseen problems arose, as well as the results of the tests conducted on the final prototype container. The results show the ability of the plastic container to withstand severe impacts over a wide range of temperatures while incurring no damage.

The minor problems which remained unresolved are currently being addressed in a follow-on plastic 155-mm propelling charge container program which is scheduled for completion in FY 87.

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INTRODUCTION

There recently has been an increased interest, within the Army, in plastic packaging for ammunition. The motivation for a change from wood/metal to plastic resulted from the desire for lighter weight packaging which is less labor intensive to fabricate, NBC decontaminable, and less expensive. The Army has initiated a research and development program to determine the feasibility of developing a plastic container capable of meeting the stringent military ammunition packaging requirements.

The first plastic container, fielded during the Vietnam War, packaged 60-mm and 81-mm mortar rounds. Due to the contractor's failures to follow fabrication specifications, however, these containers experienced stress cracking failure resulting in the need for complete repackaging of the rounds in jungle wrapped fiber tubes and wood boxes. This initial experience cost the Government a great deal of money and gave plastic packaging a bad reputation.

The only plastic container fielded since the 81-mm container is the M621 for shipping and storage of 25-mm ammunition for the Bradley Fighting Vehicle. The M621 container is currently receiving criticism because of its marginal seal capabilities. Therefore, a Product Improvement Program has been initiated to correct this deficiency.

The selected testing vehicle for the R&D program was the M490 105-mm tank round. Considering the potential size of the container required to package this round, blow molding was selected as the fabrication approach. Although considered the optimal approach, there are inherent problems associated with the blow molding process; specifically, inconsistent wall thickness and difficulty in holding dimensional tolerances.

In extrusion blow molding, thermoplastic pellets are loaded into a hopper and fed through an extrusion screw where they are plasticized. The plastic is pumped downward through a die and core which forms a hollow plastic tube known as the "parison." The parison drops down between two open mold halves which close around it, pinching off the top and bottom. A blow pin inserted into the sealed parison injects pressurized air (approx. 100 psi) which forces the molten plastic into the shape of the mold. Cooling begins at the instant the plastic contacts the mold surface, and after a designated cycle time (2 to 4 min), the mold opens and the part is removed.

A Scope of Work was prepared and solicited for the design and development of the plastic tank round container that included a material specification [high density polyethylene (HDPE)], a preliminary design concept, an internal support system design, and the testing program which included acceptance criteria. The associated research, development, and fabrication contract (DAAK10-83-C-0241) was awarded to Airmold Division, W. R. Grace, on September 28, 1983.

Extrusion blow molding is a technique used for fabricating hollow, one piece, thin walled, plastic containers and is applicable to containers with volumes ranging from a few ounces to as much as 500 gal. To illustrate this molding technique, figure 1 depicts the fabrication of a plastic milk container.

There are a few disadvantages associated with the blow molding process. Primarily, it is difficult to attain constant wall thickness and tight tolerances. The wall thickness varies as a function of the variations in the cross-sectional diameter of the mold. Walls are thickest at the areas of minimum diameter and thinnest at the areas of maximum diameter. Tolerances are primarily dependent upon shrinkage which occurs as a part cools. The degree of shrinkage varies with wall thickness, being greatest where the material is thickest. In extreme cases, variations in material thickness can result in warpage of the part. To control the wall thickness and, therefore, the shrinkage to some degree, blow molds are designed to have large radius corners and relatively constant cross-sectional diameters.

RESULTS

Design 1

The first molded prototype containers (fig. 2) were similar to the concept presented in the Scope of Work with the addition of interlocking features incorporated to improve pallet stability. The closure design incorporated an outside, double-walled cap with an O-ring-in-compression seal in which the O-ring was compressed between the top stacking section of the container body and the bottom edge of the cap (fig. 3). However, the design had no provision on the container neck for a positive stop for the cap lugs. The tightness of the cap, therefore, relied solely on the upward pressure exerted by the O-ring which forced the cap lugs up against the lugs on the container neck.

The prototype containers underwent preliminary testing at Airmold's facility. They were exposed to 3-ft and 7-ft drops at -20°F and an underwater submergence at a depth of 7 ft. The container proved successful during the drops, incurring no damage at 3 ft and only minor dents to the outside cap wall at 7 ft. However, during submergence, the container's seal failed and the container filled with water.

Test results indicated that the compression seal was inadequate. Following technical discussions, it was concluded that a compression seal was not feasible and should not be pursued any further. Therefore, the closure and seal design required modifications which resulted in a second design.

Design 2

The container closure design was modified to incorporate an O-ring-in-shear seal. A groove was molded into the container neck to accommodate a neoprene O-ring which, when compressed against the inside wall of the cap, resulted in an air tight seal. Along with the O-ring groove, lug stops were added to the neck to provide a more positive closure (fig. 4). The container cap was also modified to provide better handleability by molding additional depressions on the top (fig. 5).

A sequence of drops was performed at ARDEC to test the improved design. Before dropping, the containers underwent a 3-psi pressure retention test. An air tight seal was achieved; however, the cap was very difficult to put on an remove. Following a 3-ft drop series (6 orientations), the seal was retested and remained air tight to a pressure of 3 psi (fig. 6). As a result of the 7-ft drops, cracks were incurred in the outside wall of the cap which provided a leakage path through the blow pin hole to the inside of the container. By plugging the hole with hot melt adhesive, the seal was no longer compromised by cracks in the outside wall of the double-walled cap.

The handleability of the container cap, despite modifications, remained inadequate. Additional modifications were required to provide a better gripping surface and a gasket which would create less friction against the cap wall.

Design 3

A clay model of the modified cap (3rd iteration) was made in order to test its handleability before finalizing the cap design. After examination of the modified cap model, the cap mold was cut to incorporate these final changes (fig. 7).

To reduce the friction between the cap and the gasket, an alternate to the neoprene O-ring was required. Initially, silicon was considered; however, it was discovered to have inadequate chemical resistance and a history of causing stress cracks in polyethylene. After consulting an O-ring manufacturer, an ethylene-propylene O-ring was selected. The final container design is shown in figures 8 and 9.

Containers, incorporating all of the modifications, were fabricated and delivered to ARDEC for testing. The test program was a modified version that reflects the testing/acceptance criteria for ammunition packaging. The tests that were selected and performed were considered the most rigorous; including drop tests under low temperature conditions as well as compression tests. The containers underwent pressure retention checks before and after the drop series. Detailed test results are shown in tables 1 through 4.

Approximately 90% of the containers tested before drops passed the 3-psi pressure retention test. The assemblies that did not hold an air tight seal had slightly ovalized neck sections which created gaps between the gasket and the cap. Following the seal check, each container was dropped from a height of 3 ft onto a metal plate at six orientations. The only damage incurred was to the cap, as a result of direct impact. Very small cracks, along with minor dents, appeared on the outer wall of the double-wall cap which did not affect the seal or the ammunition. The 7-ft drop test results were similar. The cracks and dents incurred were more severe, but still did not affect the seal or ammunition in most cases. Even after a 40-ft drop, the container retained its integrity and only the outside cap walls were damaged.

Compression tests showed that, even at ambient temperature, the container could not support the required stacking load of 1,300 lb. The maximum load supported by the container and resulting in no deformation was 950 lb which would be significantly reduced at increased temperature.

During loose cargo testing, no dents or cracks were incurred.

Another problem that had not been anticipated was unequal shrinkage of the cap and neck at low temperature conditions which resulted in a loosely fitting cap. A separate study was performed to determine specifically which dimensions changed and created the loose fit at low temperature (app).

Tests were performed on containers that incorporated an antistatic additive used to reduce the surface resistivity of the HDPE to eliminate the potential threat of static buildup and electrostatic discharge. A series of drops was performed on seven containers conditioned to -60°F. All of the containers were severely damaged during the 3-ft drop series, incurring large cracks and in some cases complete severing of the container neck and body. The damage was independent of the orientation. Further analysis of these containers was discontinued.

To determine the dynamic properties of the container when subjected to various drops at different temperatures, a series of drop tests were conducted and photographed with high speed film. Containers were dropped from 3, 7, and 40 ft at -60°F, ambient, and 160°F. These tests were conducted with inert M490 tank cartridges. Three-psi pressure tests were not conducted after the drops. The results of the test showed that the damage to the containers after the 3- and 7-ft drops was limited to minor dents to the cap and scuffing. Increased denting to the cap and scuffing was observed after the 40-ft drops but the containers experienced no significant damage. An analysis of the high speed film indicated the ability of the container to absorb energy and provide protection to the packaged item.

CONCLUSIONS

It was concluded that an outside cap design would not be pursued any further based primarily upon the extra cube which such a design requires. Presently, inside cap designs are being investigated in a number of follow-on programs. Aside from reducing the container cube, the inside cap design will enable the GI to access the rounds from palletized containers (fig. 10) with greater ease.

The remainder of the problems associated with the plastic container, which are being addressed along with the improved cap design, include the following:

1. [illegible] area resulting in a poor seal

2. Difficulty in applying and removing the cover as a result of poor thread design

3. Inability of the O-ring-in-shear design to provide an air tight seal under normal atmospheric conditions

4. Inability of the container to support the required stacking load of 1,300 lb

5. Unsatisfactory performancd of containers incorporating an antistatic additive

All of the information obtained from this plastic 105-mm tank round container program is currently being applied to a plastic 155-mm propelling charge container program. It is anticipated that the inadequacies of the tank round container will be overcome with the use of an improved closure design and the addition of stacking reinforcements. Additionally, the seriousness of the safety threat imposed by electrostatic buildup on a plastic ammunition container and a list of alternative antistatic additives are currently being determined.

RECOMMENDATIONS

Based on the favorable results of this program and the potential cost savings involved, it is recommended that further investigation be conducted with respect to the use of plastics for ammunition packaging.

Table 1. Test conducted on design 3, 3-ft drop-ambient

Container	Orientation						Pressure test
	Top	Bottom	Side	Side	Top edge	Bottom edge	
1	+	–		–	++		No test
2	+	–	–	–	++	–	No test
3	+	–	–	–	+	–	No test
4		*	–	–	+	–	No test
5	+	–	–	–	++	–	No test
6	+	–	–	–	+	–	No test

– = No damage.
+ = Slight denting of cap.
++ = Slight denting and cracking of cap.
* = Minor crack in bottom of container.

Table 2. Test conducted on design 3, 3-ft drop-cold

Container	Orientation						Pressure test
	Top	Bottom	Side	Side	Top edge	Bottom edge	
1	+	–	#	–	++	–	P
2	+	#	–	–	++	–	F
3	+	–	#	–	++	–	No test
4	+	–	–	–	++	–	No test
5	+	–	*	–	++	–	No test
6	+	–	*	–	++	–	No test

– = No damage.
+ = Slight denting of cap.
++ = Denting and cracking of cap.
# = Loosening of cap.
* = Cracking of body.

Table 3. Test conducted on design 3, 7-ft drop-ambient

Container	Orientation						Pressure test
	Top	Bottom	Side	Side	Top edge	Bottom edge	
1		-					F
2	+						P
3					++		F
4						-	F
5			-				No test
6				-			No test

- = No damage.
+ = Denting of cap.
++ = Denting and cracking of cap.

Table 4. Test conducted on design 3, 7-ft drop-cold

Container	Orientation						Pressure test
	Top	Bottom	Side	Side	Top edge	Bottom edge	
1					+++		P
2	+++						F
3	No test						No test
4	No test						No test
5	No test						No test
6	No test						No test

+++ = Denting and severe cracking of cap.

BLOW MOLDING

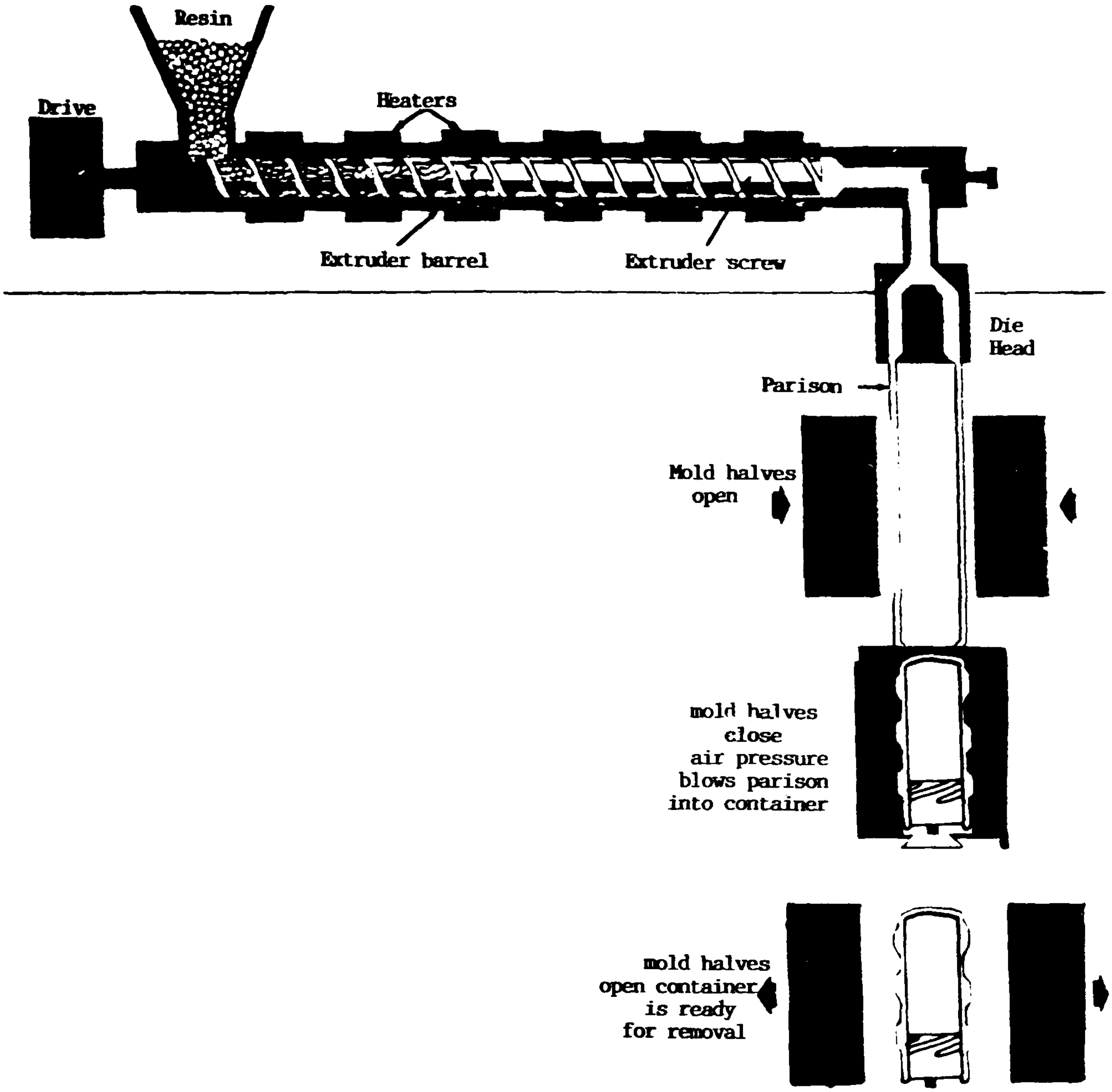

Figure 1. Blow molding

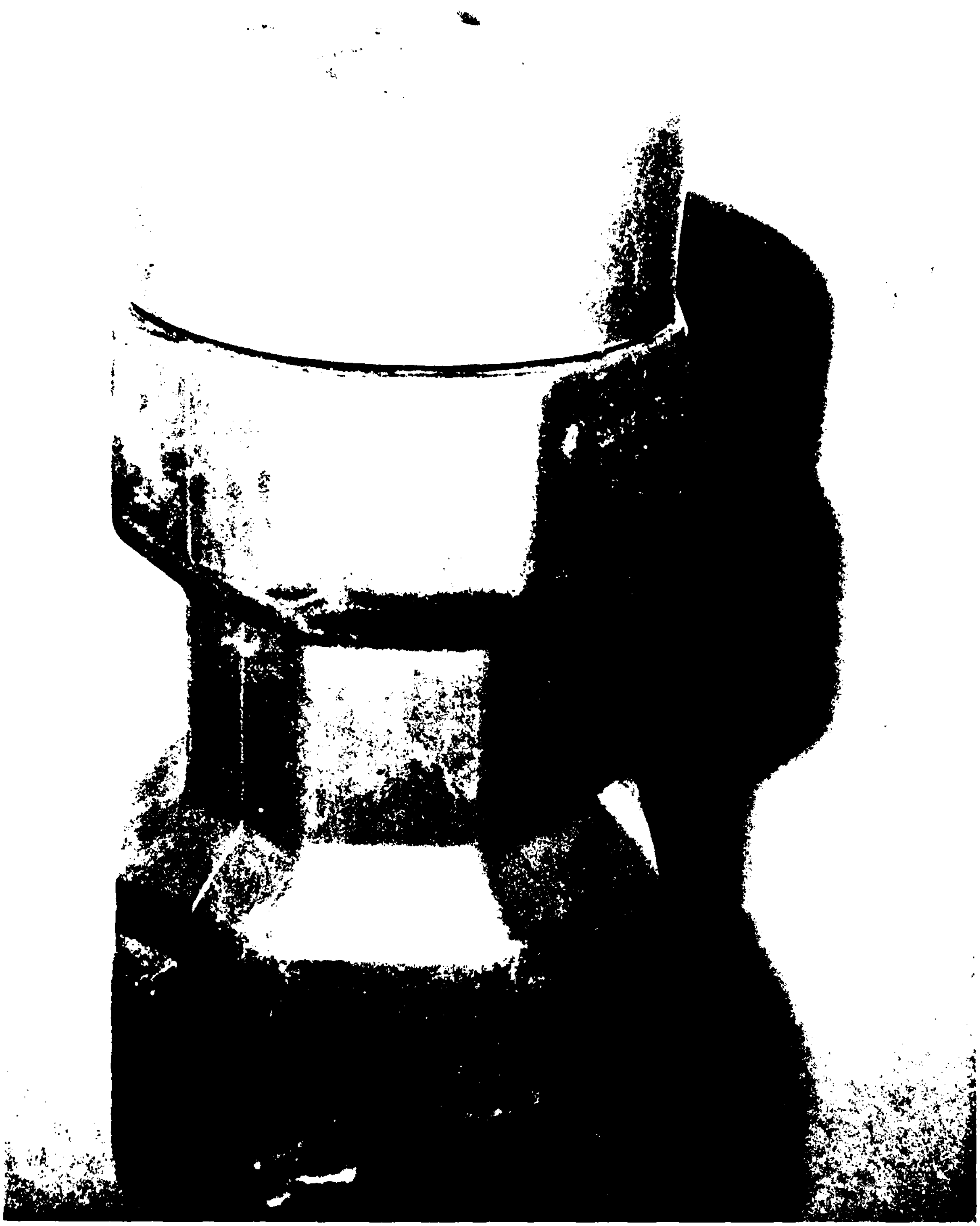

Figure 2. Initial design

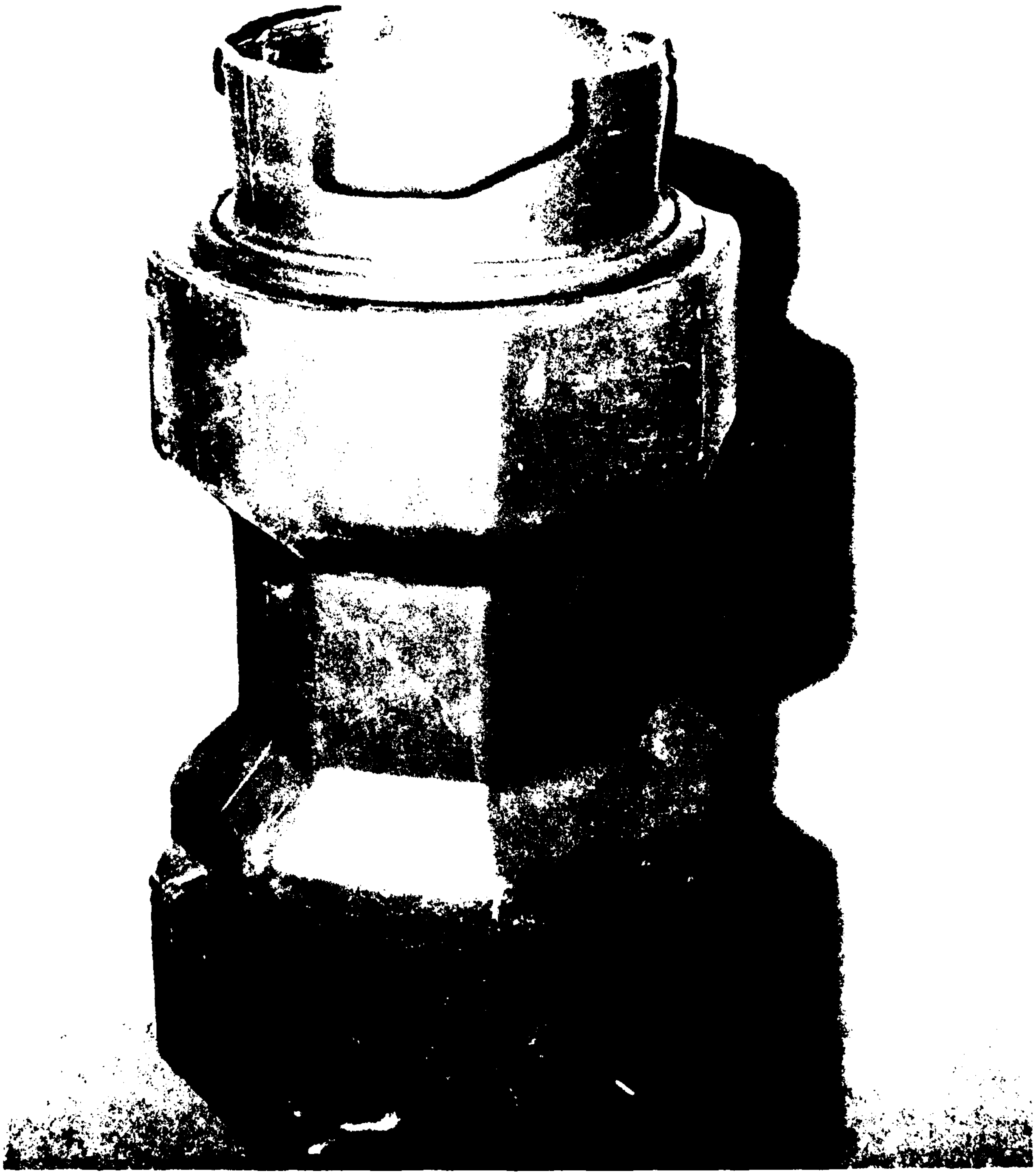

Figure 3. O-ring-in-compression design

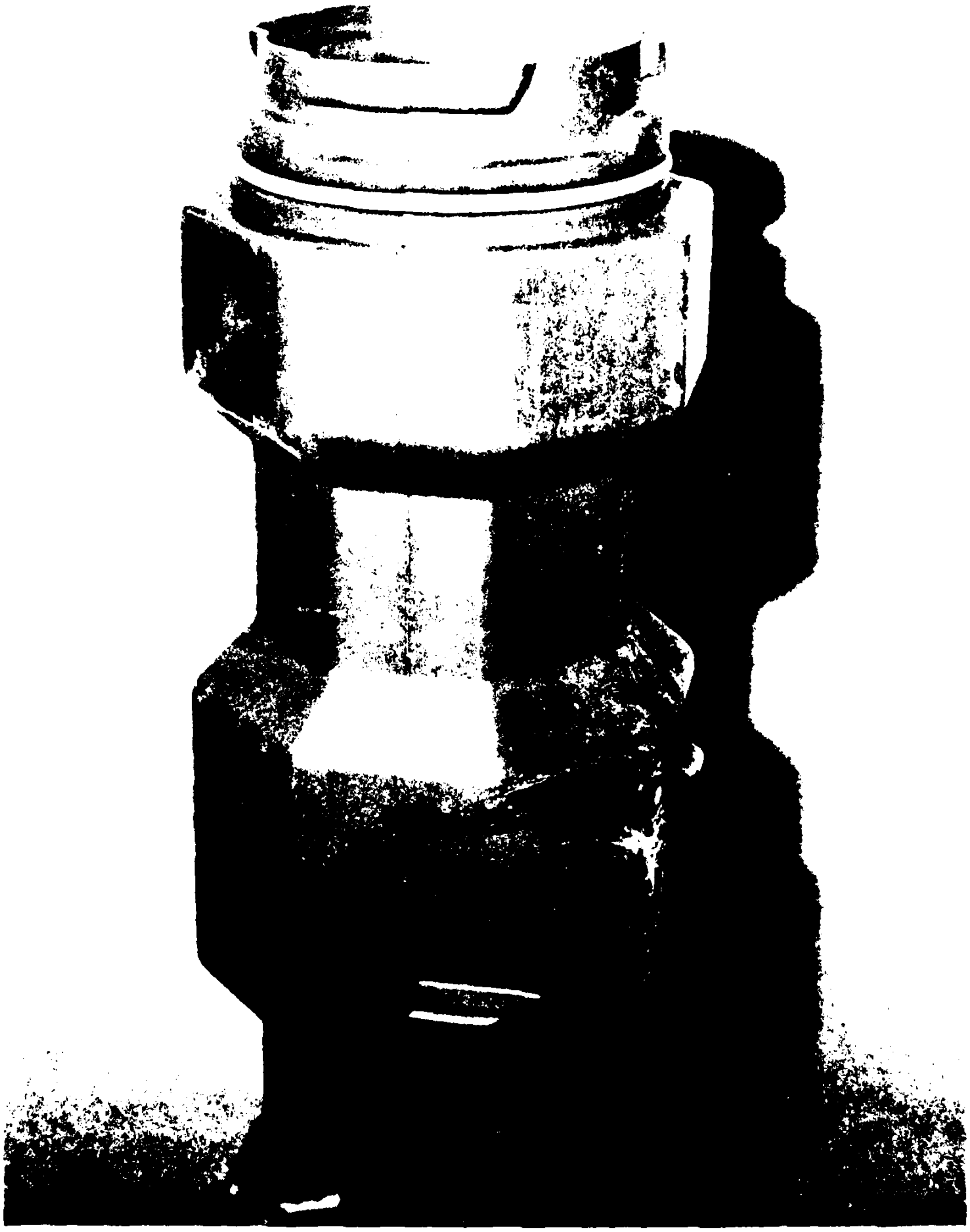

Figure 4. O-ring-in-shear design

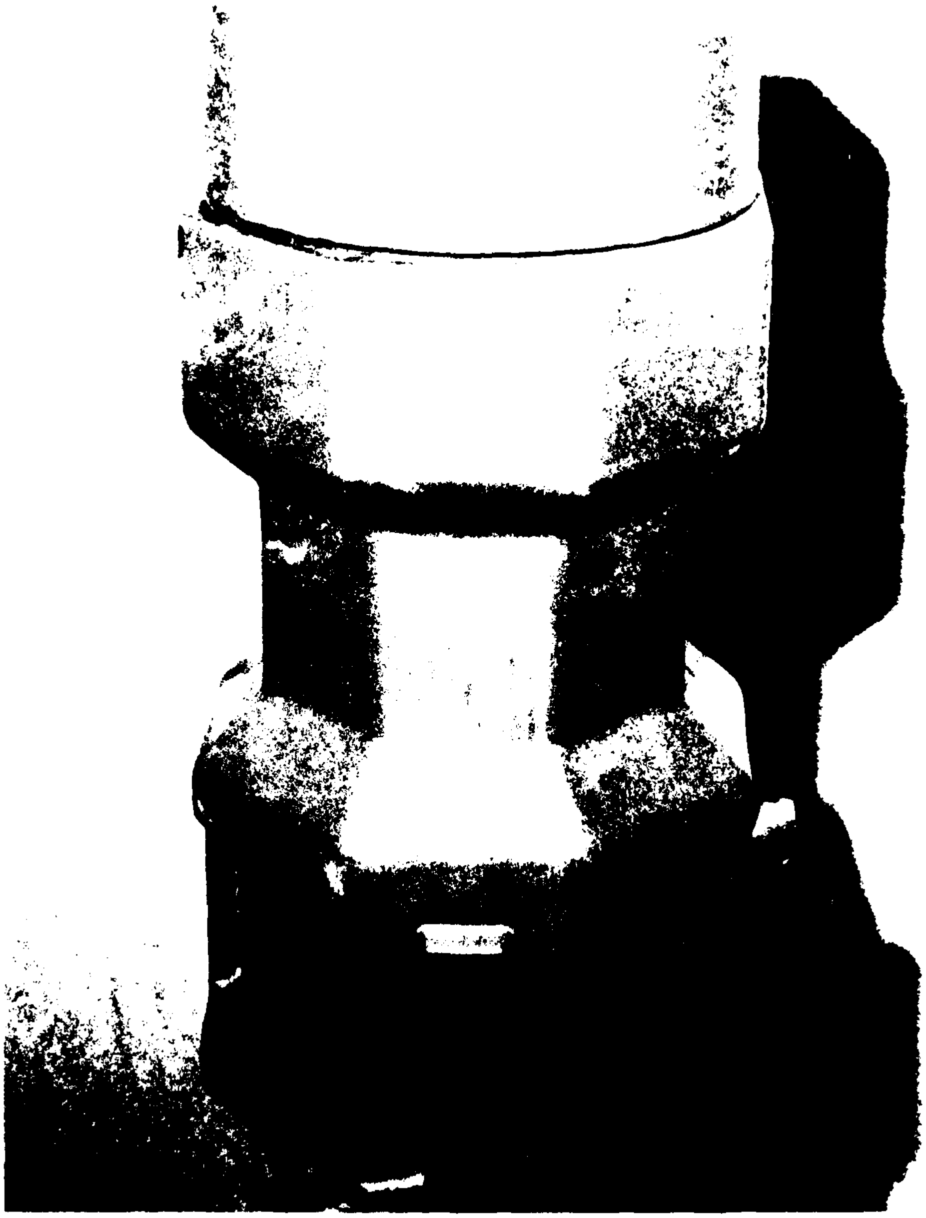

Figure 5. Modified cover design

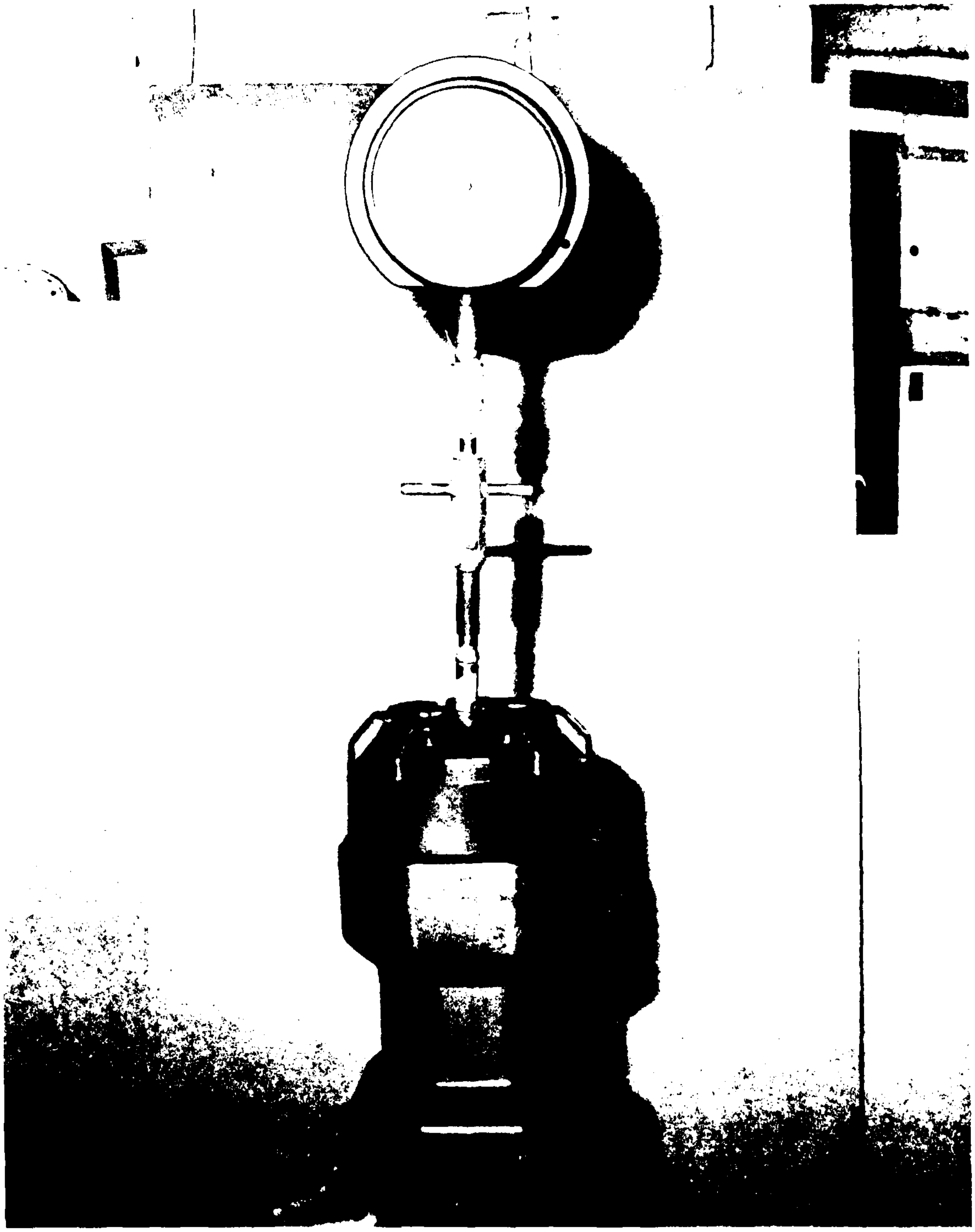

Figure 6. Three psi seal

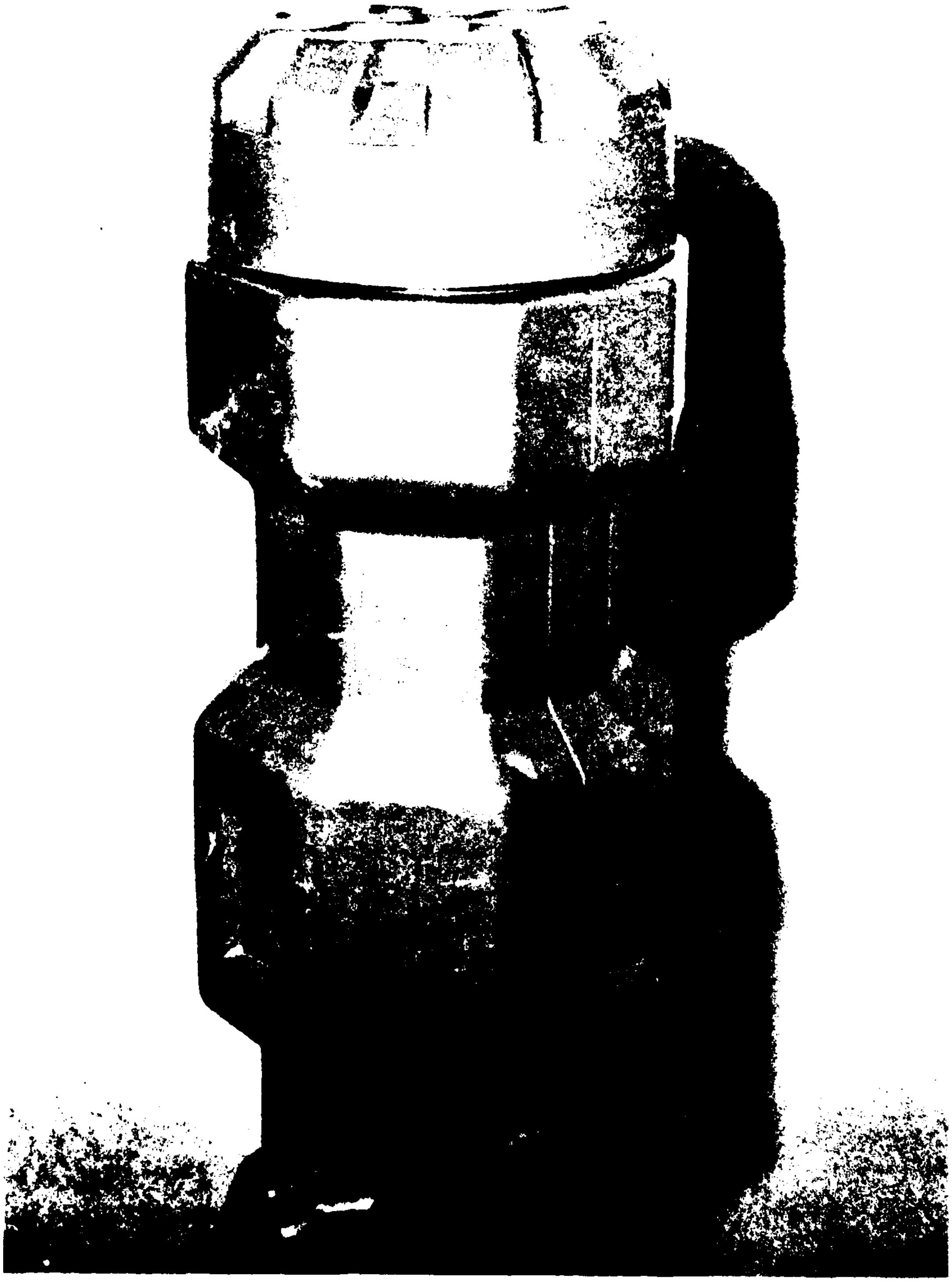

Figure 7. Final cover design

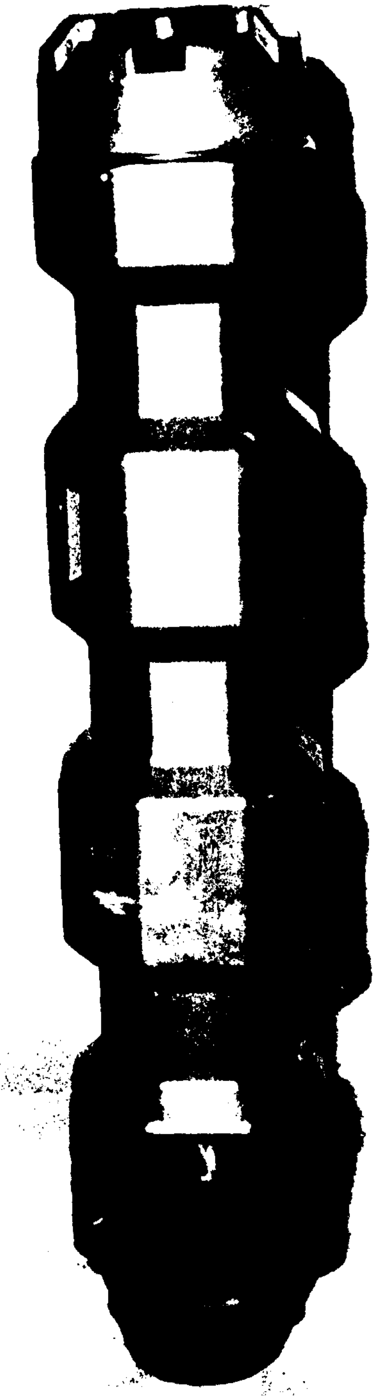

Figure 8. Final design--view 1

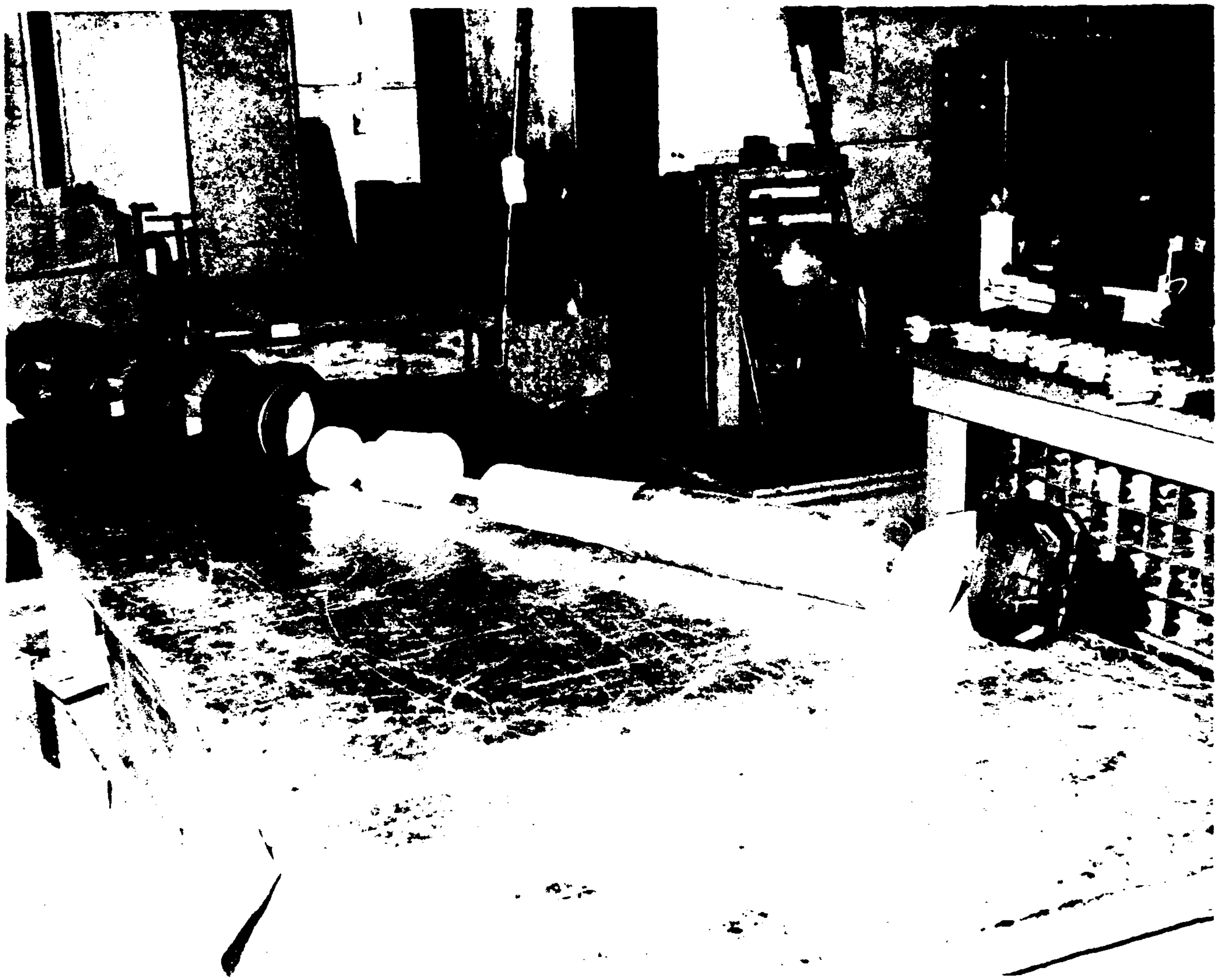

Figure 9. Final design--view 2

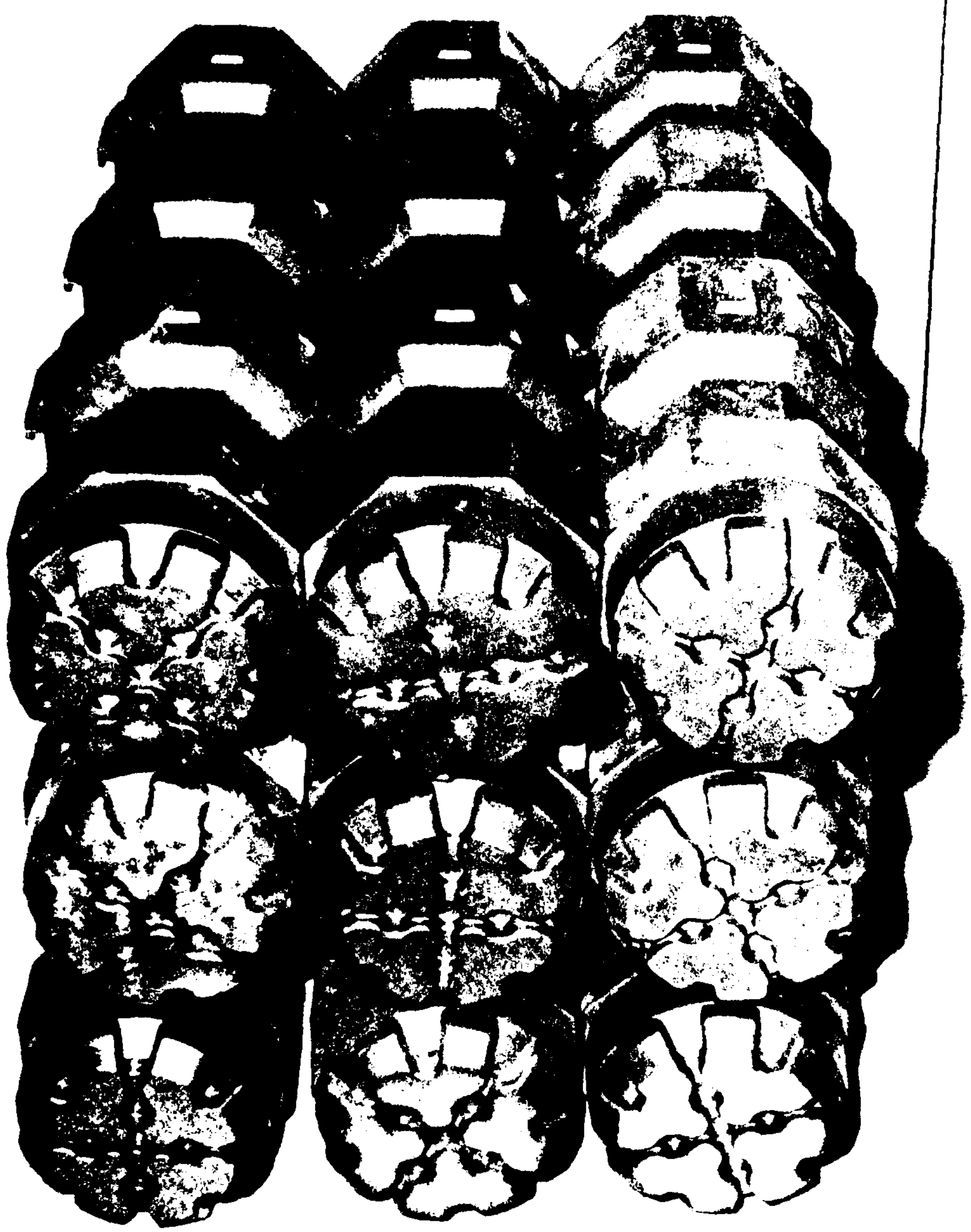

Figure 10. Pallet Configuration

APPENDIX

THERMAL SHRINKAGE STUDY

The plastic blow molded 105-mm tank round container has undergone a number of tests including a series of drop tests at ambient and cold (-60°F) temperatures. Under cold conditions, the container cap became loose. To determine the specific reason for the loosening, a series of measurements was taken on the container under ambient and cold conditions.

To obtain data, container neck diameters were measured at three locations: above the gasket, below the gasket, and on the gasket itself (fig. A-1). Three measurements were taken at each location, one from pinch line to pinch line (thickest section) and two other random locations. Two containers were sampled, one with an O-ring gasket and the other with a quad-ring gasket. Each of the containers were measured at ambient and later at -60°F. The inside diameters of two container caps were also measured, but due to inadequate measuring equipment, the results were insignificant.

The data obtained from the measurements (table A-1) showed that two important phenomena occurred at cold temperatures. First was the variation in shrinkage between the thick section (pinch line) and the rest of the container neck. The shrinkage was significantly greater at the pinch line resulting in an inability to hold tolerances with the container cap which should shrink uniformly. The other observation was that the gasket, specifically the O-ring, shrank more than the container neck. Both of the shrinkage phenomena observed resulted in a loose cap at -60°F and must be corrected so that the container meets the seal criteria.

Table A-1. Container neck diameters (in.)

Measurement locations		O-ring container			Quad-ring container		
		Ambient	Cold	Shrinkage	Ambient	Cold	Shrinkage
1. Top neck	A	7.2312	7.1833	0.0479	7.2021	7.1497	0.0524
	Avg B + C	7.1035	7.0758	0.0277	7.1189	7.0943	0.0246
2. Bottom neck	A	7.2905	7.2480	0.0425	7.2668	7.2292	0.0376
	Avg B + C	7.1963	7.1801	0.0162	7.2151	7.1890	0.0261
3. Gasket	A	7.3048	7.2365	0.0683	7.2754	7.2312	0.0442
	Avg B + C	7.2330	7.1891	0.0439	7.2240	7.1817	0.0423

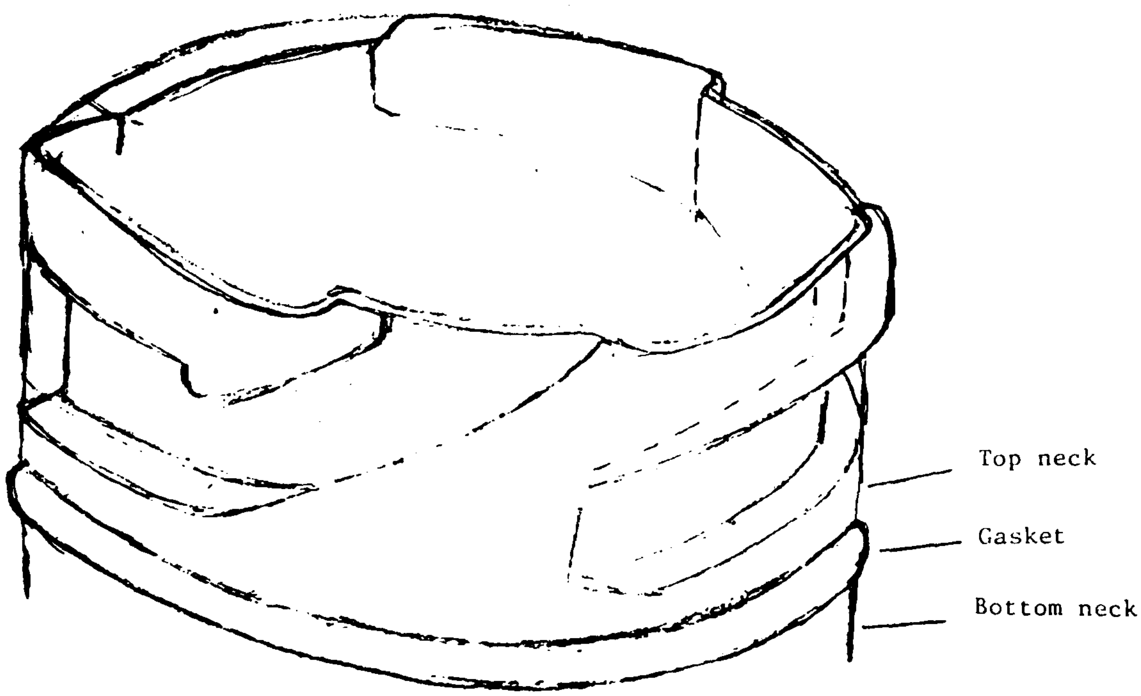

Figure A-1. 105-mm tank round container neck section

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